Mapping the Progression of Non-Carious Cervical Lesions

by

Malcolm. J. Grenness
B.D.Sc., L.D.S., M.Med.Sc.,
F.R.A.C.D.S.

Spatial Information Sciences Group
School of Geography and Environmental Science
(University of Tasmania)

Submitted in fulfilment of the requirements for the
Degree of Doctor of Philosophy

(June 2008)

Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any tertiary institution, and to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Signed:

M.J. Grenness

Disclosure

The author Grenness is named on a patent associated with the use of materials with improved optical texture.

Statement of Co-Authorship

The following people contributed to the publication of the work undertaken as part of this thesis:

Grenness, M.J., Osborn, J.E. and Tyas, M.J., 2005. Stereo-Photogrammetric mapping of tooth replicas incorporating texture. Photogrammetric Record 20 (110), 147-161. (Chapter 5, excluding appendix)

	Candidate (Author 1) , %	Author 2 , %	Author 3 %
Conception	> 90	< 10	< 5
Experimental design	> 90	< 5	< 5
Experimental work	100		
Analysis	100		
Writing	> 95	< 5	< 5

Grenness M.J., Osborn J.E. and Tyas M.J., 2005. Digital very close range photogrammetry of a test object incorporating optical texture. 7th Optical 3D Measurement Techniques, Oct 3-5, Vienna, Austria. (Chapter 6, not refereed)

	Candidate (Author 1) , %	Author 2 , %	Author 3 %
Conception	> 90	< 10	< 5
Experimental design	> 90	< 5	< 5
Experimental work	100		
Analysis	100		
Writing	> 95	< 5	

The undersigned agree with the above stated "proportion of work undertaken" for each of the above published manuscripts contributing to this thesis.

Signed:

M. J. Grenness

School of Geography and Environmental Science
University of Tasmania

Abstract

'Non-carious cervical lesion' (NCCL) is a term used to describe loss of hard tissue in the cervical one-third of teeth. NCCLs are commonly encountered in dental practice and frequently require clinical intervention. There are few reports of high quality mapping and monitoring of NCCLs, and dental practitioners currently have no reliable method for measuring and monitoring their progress. Improved understanding of the underlying causes and progression of NCCLs will rely on reliable and practical methods of mapping their topography and monitoring their progress.

NCCLs on the facial surfaces of teeth can be easily imaged, either directly or on cast replicas, and therefore may be well suited to mapping using a photogrammetric approach. A preliminary investigation led to the development of a casting material that incorporated optical texture so that photogrammetric image-matching techniques could be utilized.

Three-dimensional coordinate data for tooth replicas was successfully generated using the casting material, convergent stereoscopic photography and commercial digital photogrammetric software. Imaging was performed initially using a semi-metric 35 mm film camera, then a high-resolution digital SLR camera, and finally a fixed-base digital SLR stereo camera. The quality of the surface data and the capacity to align tooth surfaces was investigated. Two specific examples of NCCLs were mapped and monitored at baseline, 12 month and 24 month time periods.

For the film camera and the single digital camera, the photogrammetric solutions were not highly stable, with systematic height errors of up to 80 μm attributed to unstable exterior orientation. However, for the fixed-base stereo camera, model precision was shown to be in the order of 13 μm and the accuracy of surfaces derived from automatic measurement was approximately 3 μm. The error associated with aligning independent measurements of tooth surfaces was approximately 17 μm. Change detection

of the two NCCL surfaces was sensitive to 30 μm, with change ranging from 30 to 320 μm per annum for one surface and 30 to 70 μm per annum for the second surface. Different rates of change were clearly evident in different areas of the same surfaces. The replication, stereoimagery, photogrammetric processing, and detection of changes to the surfaces were shown to be reliable and convenient.

The results of this investigation show that stereo-photogrammetric techniques can be applied to the mapping of NCCLs, and that the surfaces can be mapped at sufficient accuracy to enable change to be monitored. The two examples suggest that annual change detection studies will provide a clearer picture of the rate of progression and the geometry of progression and, in combination with other analytical techniques, a more detailed explanation of the natural history of non carious cervical lesions.

Acknowledgments

I wish to express my sincere gratitude to many persons whose generosity and helpfulness have contributed to this thesis.

I am extremely grateful to my supervisors, Dr. Jon Osborn and Professor Martin Tyas, for their invaluable guidance, advice, patience and understanding during the supervision of this thesis. Their deep knowledge and experience in their respective fields have been central to the arrival at an outcome far in excess of my initial expectations.

My thanks to the staff at the School of Geography and Environmental Studies, The University of Tasmania, for their kind support. I owe special thanks to Dr Tony Sprent for his assistance with the design and fabrication of components for the imaging equipment and to Dr. Christopher Watson and Assoc. Prof. Richard Coleman for assistance with MATLAB software programming. I thank Keith Bolton for preparation of photoplots.

I am indebted to John Farrow (School of Fine Art), Jeff Bester (Ash Bester Photographics), Fred Koolhof (Koolhof Enterprises), Alex Nazarov (Hobart Photographic Society) and the staff at Walch Optics (Hobart) for assistance and advice in photography, photographic accessories and lens design and application.

Thanks also go to Jason Birch and Yongru Huang of ADAM Technology P/L, Perth, Australia for technical support and modification of their software products, and to Dr. Harvey Mitchell from University of Newcastle for providing access to DS Match proprietary software.

Finally, I acknowledge my family, Susan, Alasdair and Emily, for their patience and forbearance of the many, many evenings and weekends where I disappeared to conduct the endless hours of modeling and analysis for this thesis.

Table of Contents